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SUPPLEMENT
TO

GRAVITY GRADIENT ROD THERMAL BENDING TEST REPORT

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1. PURPOSE

The purpose of this supplement is to report the results obtained in the rod thermal gradient and α_{IR} tests which were being conducted at the time the program final report was prepared. These tests were mentioned in Section 5.2.4 of Reference 1.

2. RESULTS

The thermal bending test results reported in Reference 1 are revised here as Table 2 to reflect the more correct value of the rod α_{IR} determined in this test. The corrected values for magnitude of bending are seen to be reduced to an average of 46 percent of predicted values.

3. RECOMMENDATIONS

Completion of this test series indicates that actual measured thermal deflections are on the average, 46 percent of those predicted by theory. These results indicate that the recommendations made in Reference 1, page 3-1, are the minimum necessary to refine the theory of rod thermal bending so that it will adequately explain the phenomena. In addition, it is felt that the analysis presented in Appendix C of Reference 1 is an excellent attempt to understand the behavior of the rods and completion of the work through numerical results would help greatly in the work being done in the field.

4. TEST DESCRIPTION

As noted in Section 5.2.4 of Reference 1, this test was necessary to obtain temperature gradients around the test rod as a function of sun/rod angle. It was originally planned to perform this evaluation concurrently with the bending tests in the large chamber, but it was physically impossible to either rotate the temperature gradient specimen in the flux field or have it on the same centerline as the bending test specimen. Therefore, this test was conducted in the Thermal Technologies Laboratory.

5. TEST SETUP

Figures 1, 2 and 3 show the test setup. The test rod with its 12 5-mil, copper-constantan thermocouples, and the heat flux source were suspended 20 inches apart from the black-painted framework shown. The liquid-nitrogen cooled vacuum bottle then fits snugly against the base plate of the setup and is evacuated to the desired level (10^{-5} torr for this test). The rod could be rotated through the eight positions shown in Figure 4 which are the same positions shown in Figure 5-6 of Reference 1.

The heat source was a 0.020-inch diameter tungsten wire mounted identically to that used in the original tests. Flux output was monitored through four thermocouples mounted on black-painted plates in the flux field. These can be seen in Figures 2 and 3.

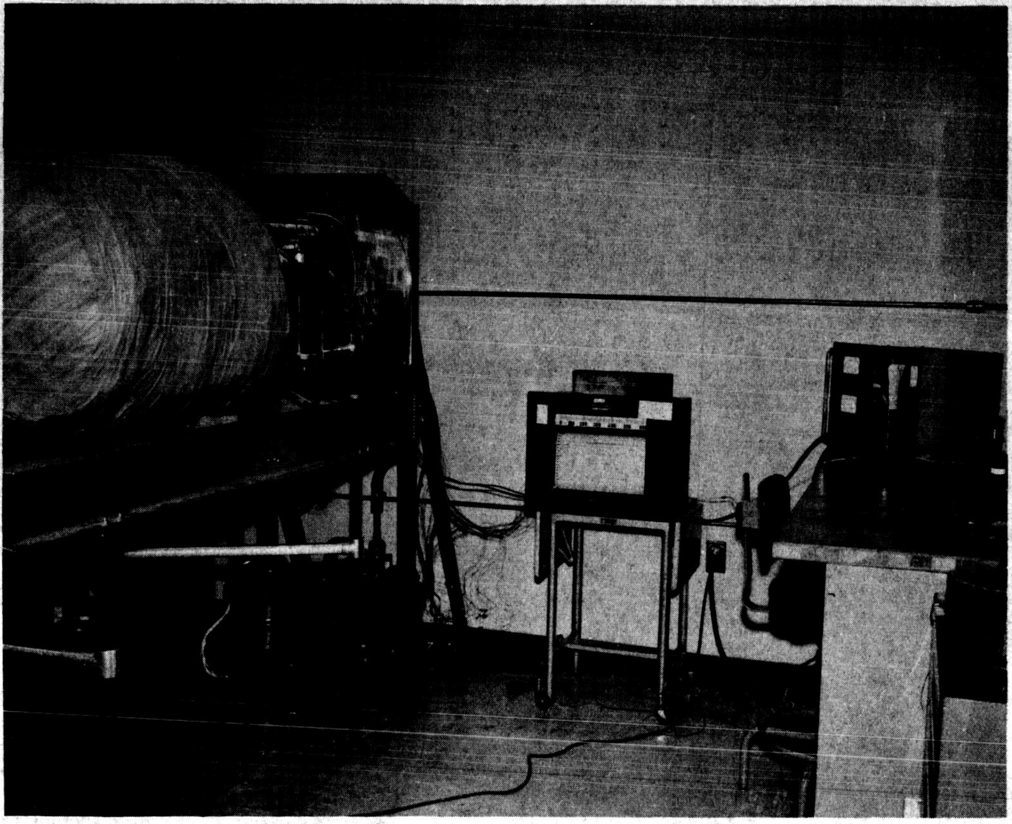

Figure 1. Overall Test Setup

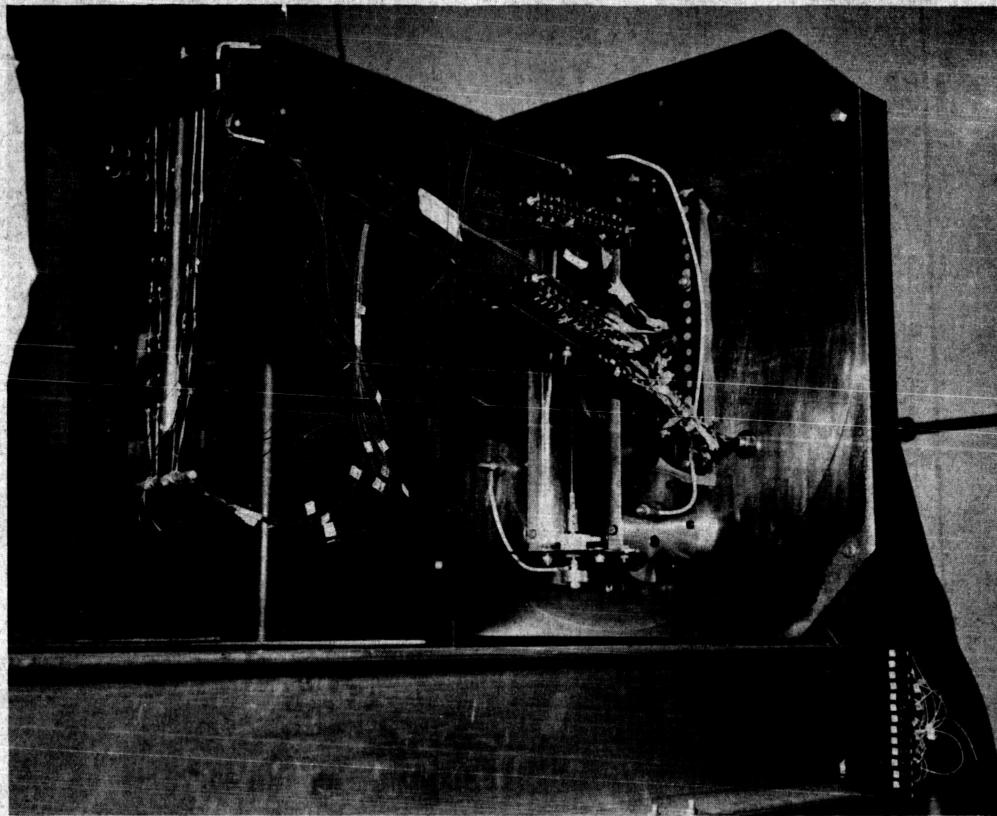

Figure 2. Closeup of Rod-Heater Assemblies (Right-Hand View)

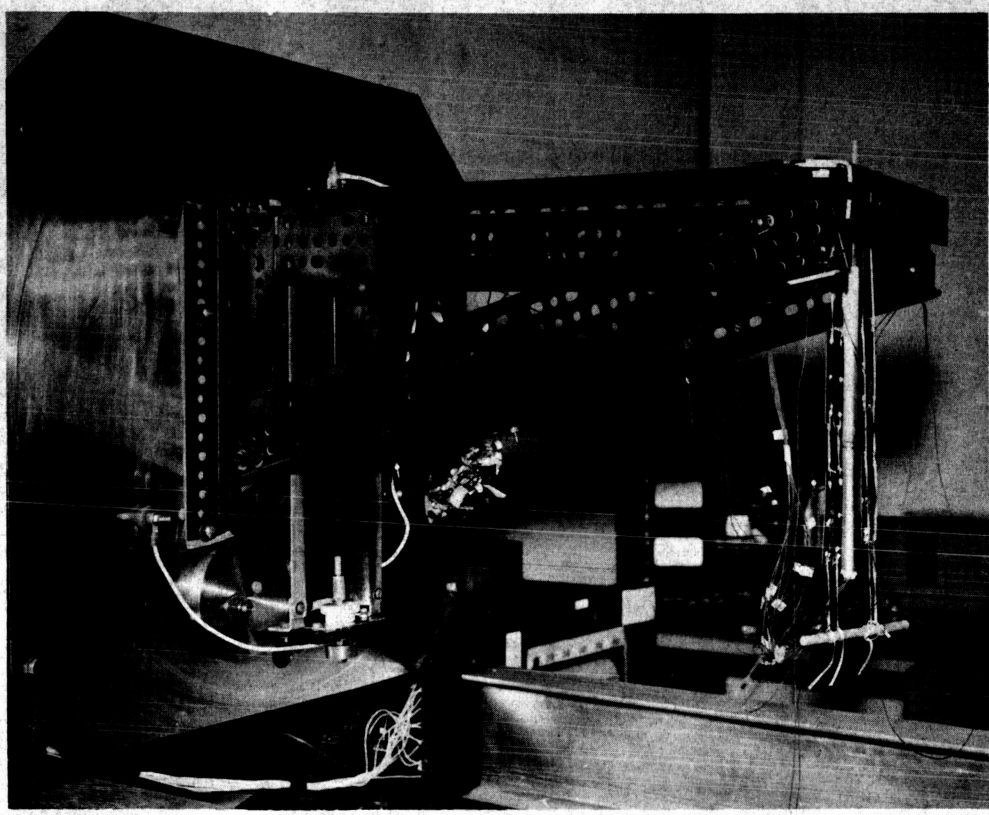

Figure 3. Closeup of Rod-Heater Assemblies (Left-Hand View)

6. TEST PROCEDURE

The flux source assembly and the test rod were checked for orientation and parallelism. The chamber was closed, pumped down to the required level and the walls cooled. Power was applied to the tungsten wire gradually until the four monitoring thermocouples reached the required temperature. When the rod thermocouples reached equilibrium conditions, readings were taken and the system shut down for rotation of the test rod to the next position. (Figure 4 shows the orientation of the test rod and flux source.)

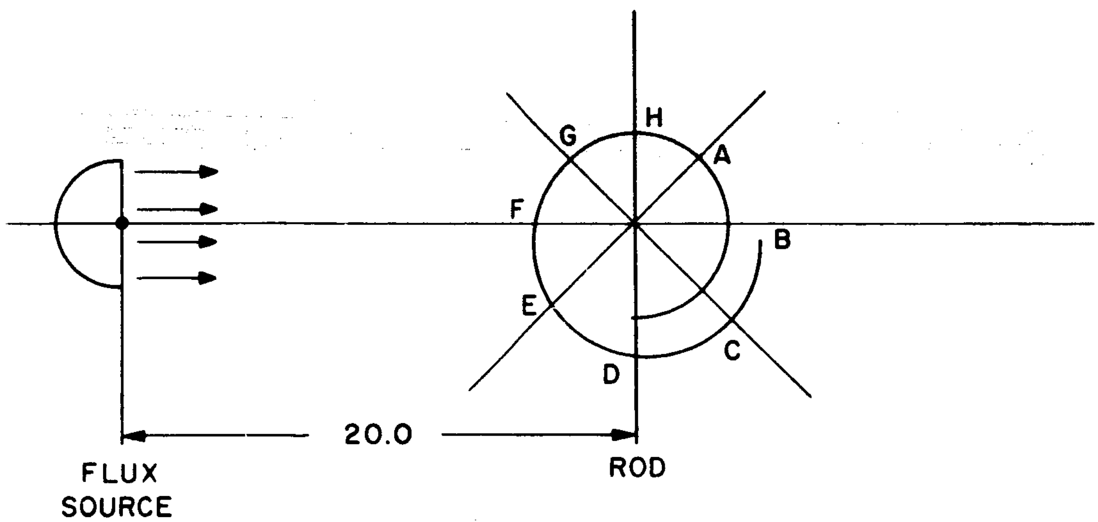

Figure 4. Orientation of Rod and Flux Source

7. TEST RESULTS

This test was conducted to:

1. To check experimental temperature variations around the circumference of the test rod against the predicted variations, and

2. To experimentally determine the α_{IR} of the rod material.

Only enough positions were checked to establish the relationships of interest.

The test results are listed in Table 1. Predicted temperature gradients for each rod orientation versus actually measured gradients are plotted in Figures 5, 6 and 7. The predicted curves are the same as those shown as Figures A-22, A-25 and A-26 in Reference 1.

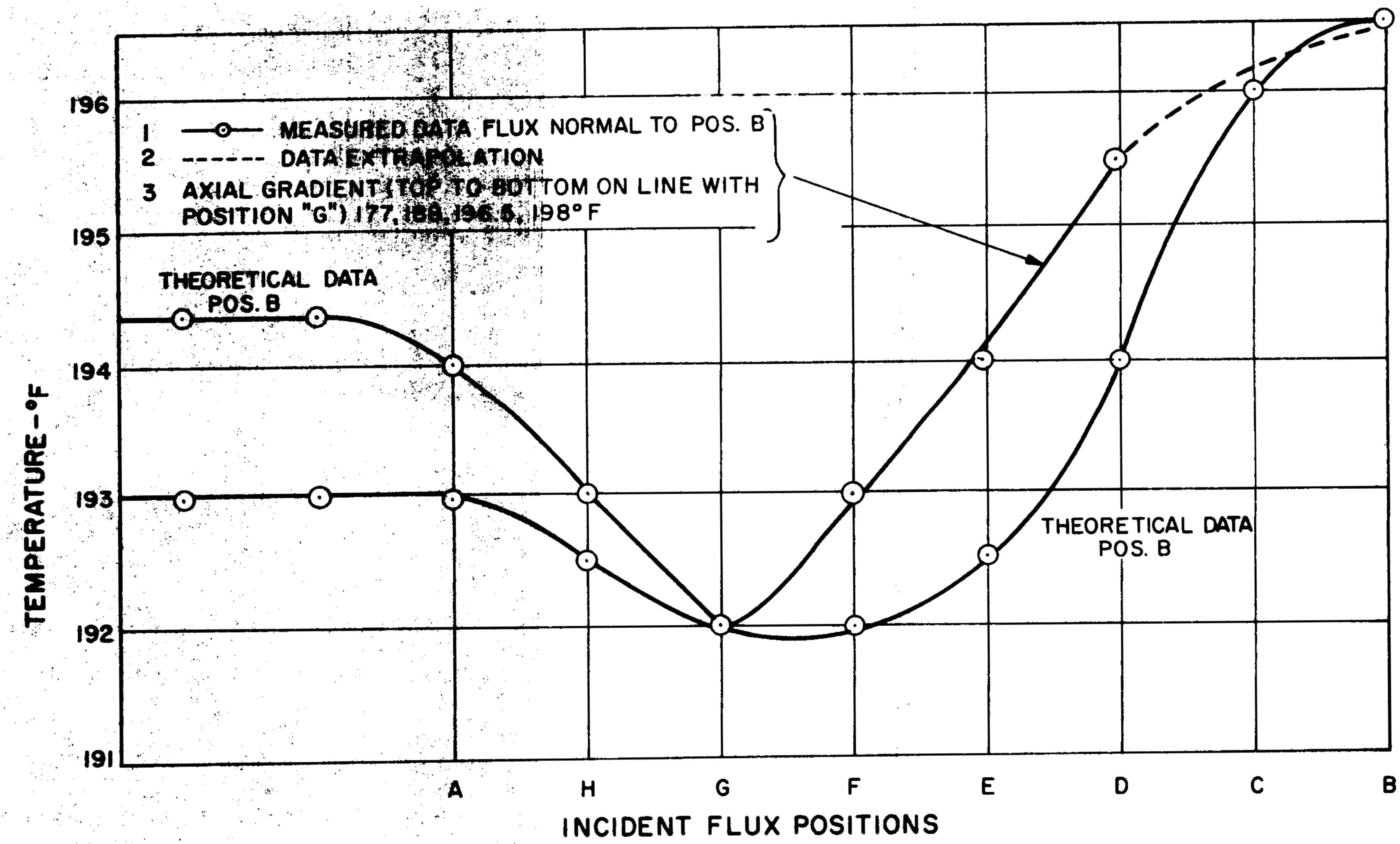

Figure 5. Theoretical and Measured Values of Test Rod Temperature Distribution

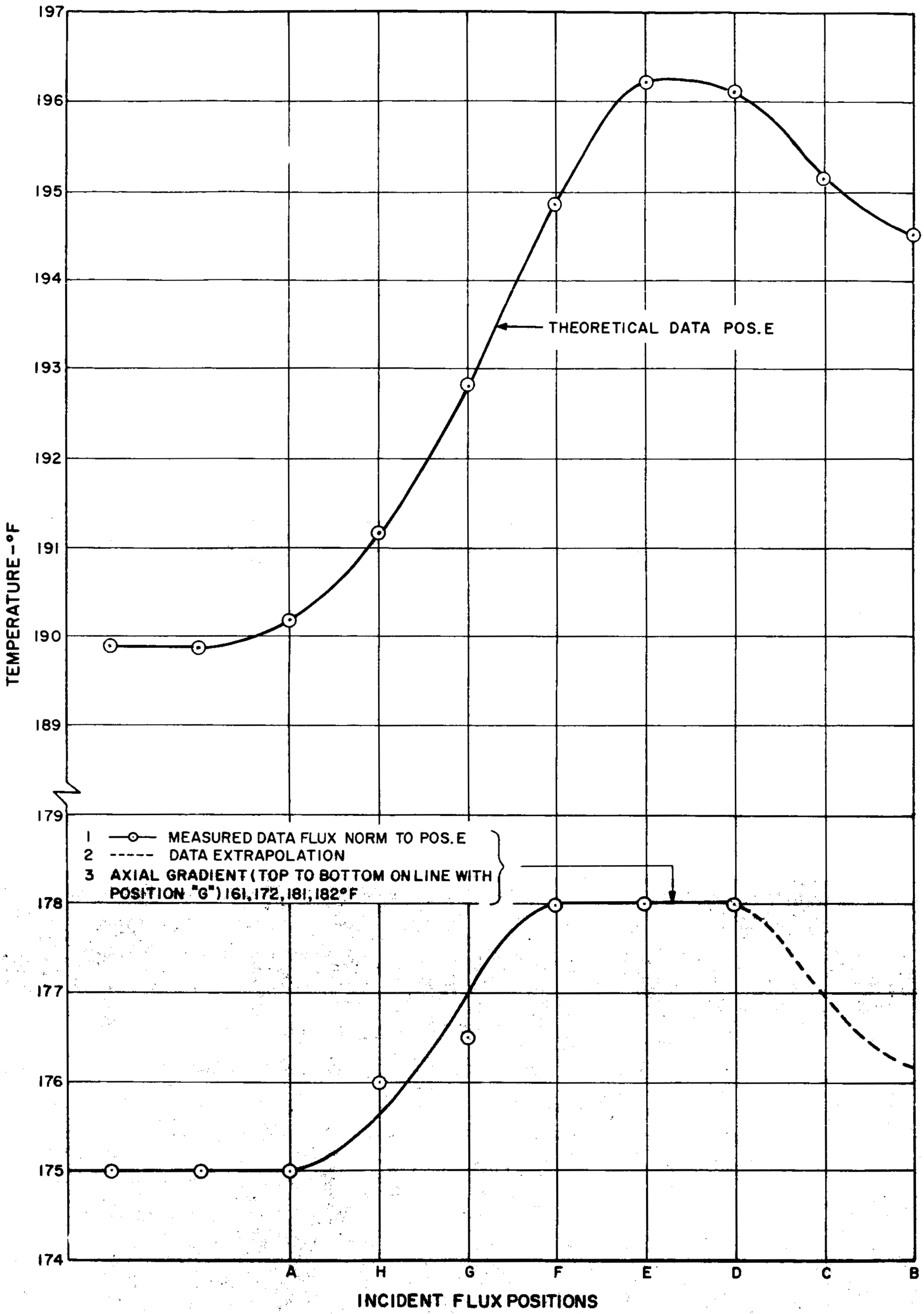

Figure 6. Theoretical and Measured Values of Test Rod Temperature Distribution

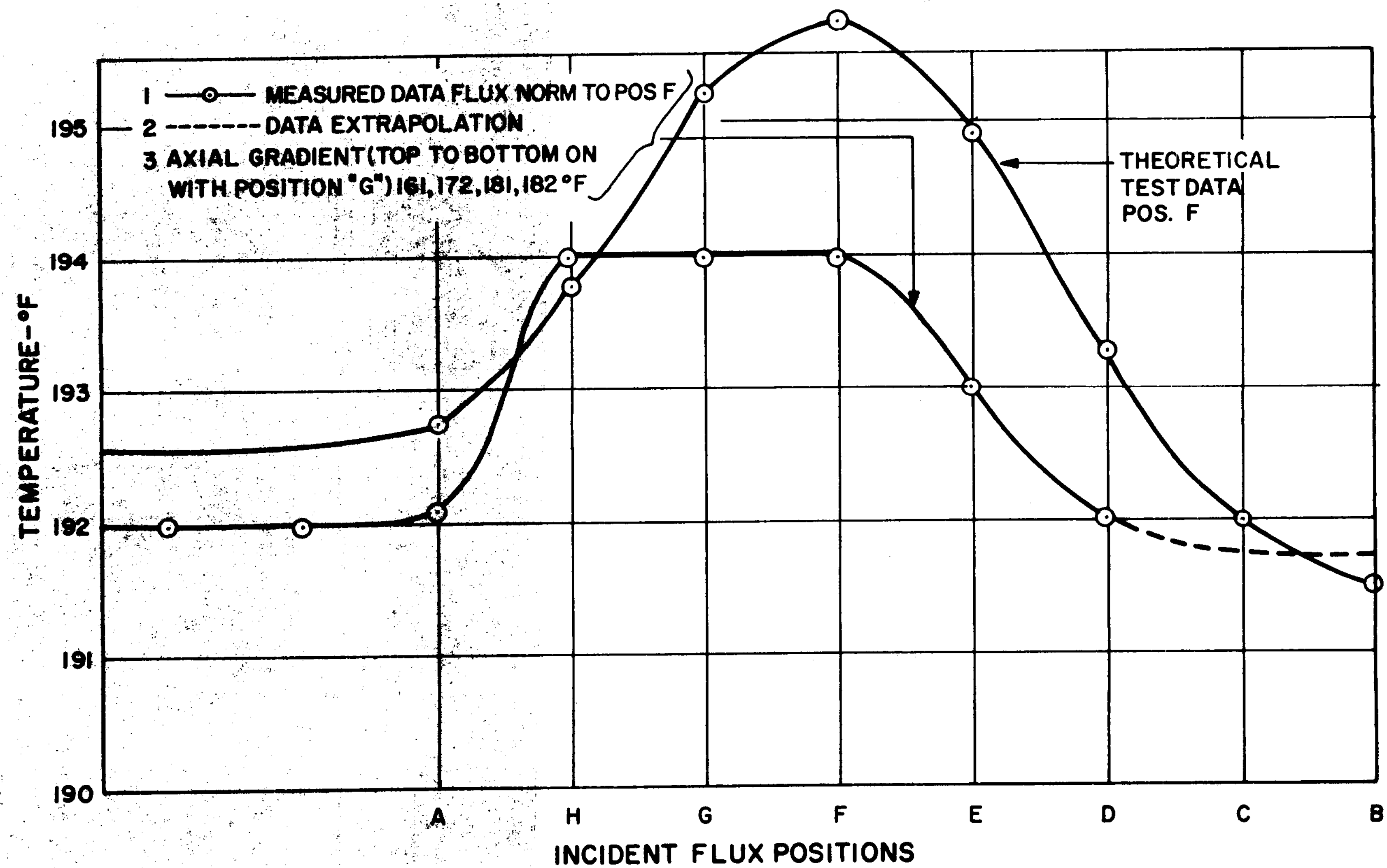

Figure 7. Theoretical and Measured Values of Test Rod Temperature Distribution

TABLE 1. TEST RESULTS

Sun Position	Flux Level (Btu/hr-ft^2)	Equivalent Suns	Measured Maximum Circumferential Temperature Gradient	α_{IR} Calculated from Measured ΔT in Gravity Gradient Rod	α_{IR} Calculated from Average Measured Rod Temperature	α_{IR} Calculated from Rod Temp. in Tests of Ref. 1
B	690	0.51	3.5	0.136	0.142	0.106
E	595	0.44	3.0	0.135	0.148	0.106
F	580	0.29	2.0	0.083	0.15	0.106

8. DISCUSSION OF TEST RESULTS

Of the three tests run in this series, the data for position F is not used because of discrepancies in the temperature measurements. The average value of α_{IR} calculated from the average measured rod temperatures is used in the following discussions. This method of determining α_{IR} is considered to be more accurate then the Δ t method discussed in Section 5.3.3 of Reference 1.

The more accurate value of α_{IR} determined in this test series required that the results presented in Tables 5-1 and 5-2 of Reference 1 be recalculated. These new results are presented as Table 2. The modifications appear in the equivalent sun and one-sun measured rod deflection columns.

In general, correlation is good between the theoretical and measured values of temperature distribution around the test rods as shown in Figures 5, 6 and 7.

TABLE 2. TEST CALCULATIONS

Date	Sun Position	Flux Level	Equivalent Suns	THERMAL DEFLECTION One g Measured	Zero g Calculated from one	One Sun Deflection Calculated	One Sun Deflection Measured	α_{IR} Calculated	ϵ_{IR} Measured	Angle of Bending Plane With Respect to Flux Plane (Deg)
September 1, 1964	A	1300	0.882	0.233	0.244	0.627	0.276	0.146	0.06	-20.3 (South)
	B	1360	0.922	0.267	0.277	0.696	0.300	0.146	0.06	-11.9 (South)
	C	1395	0.945	0.266	0.279	0.765	0.295	0.146	0.06	-7.5 (South)
	D	1365	0.924	0.248	0.258	0.644	0.279	0.146	0.06	-2.32 (South)
	E	1395	0.945	0.271	0.282	0.605	0.298	0.146	0.06	-18.5 (South)
	F	1395	0.945	0.334	0.347	0.678	0.367	0.146	0.06	-12.1 (South)
	G	1205	0.817	0.311	0.328	0.737	0.402	0.146	0.06	+0.92 (North)
	H	1240	0.840	0.244	0.252	0.726	0.300	0.146	0.06	-28.2 (South)
October 5, 1964	A	1320	0.895	0.227	0.238	0.627	0.266	0.146	0.06	-22.0 (South)
	B	1330	0.901	0.308	0.318	0.696	0.353	0.146	0.06	-5.6 (South)
	C	1330	0.901	0.233	0.246	0.765	0.273	0.146	0.06	-11.0 (South)
	D	1330	0.901	0.257	0.277	0.644	0.308	0.146	0.06	-10.8 (South)
	E	1330	0.901	0.331	0.345	0.605	0.383	0.146	0.06	-21.6 (South)
	F	1395	0.945	0.343	0.358	0.678	0.379	0.146	0.06	-13.4 (South)
	G	1320	0.895	0.335	0.354	0.737	0.396	0.146	0.06	-1.68 (South)
	H	1330	0.901	0.276	0.286	0.726	0.318	0.146	0.06	-11.5 (South)

9. REFERENCES

1. Gravity Gradient Rod Thermal Bending Test Report, Benton, W. G., Mazur, E. M., and Katucki, R. S., General Electric Spacecraft Department Document 64SD4368, 23 October 1964.